Code Implementation for Morphological Analysis of Shapes

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Advances in low-level and intermediate-level image processing enable efficient filtering, low-level feature extraction, and compression of image data. However, the key to the information contained in images lies in the ability to identify objects, features, and their interrelationships. With certain exceptions, the task of understanding images at large is done with direct human intervention and inspection. As image sensors gain sophistication in various military and civilian applications, constant human inspection of the glut of image data produced becomes tedious and expensive. As a result, the automation of Image Understanding is imperative to the efficiency of most vision sensing applications.

What makes our approach unique is that the usual pixel image is recast in terms of objects, structures and their interrelationships which results in identification of objects of interest much more quickly and with higher data compression than is done today. These improvements

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are accomplished by using a nonuniform triangular mosaic representation (Delaunay tesselation) of a scene (cf., e.g., the three persons in the figure). The triangular mosaic tile pattern is converted to semantically labeled features (limbs and torsos) [1, 2], which provide the building blocks for shape characterization.

In Tables 1 and 2, the steps leading to shape feature extraction are given in sequence. Initally a bi-level

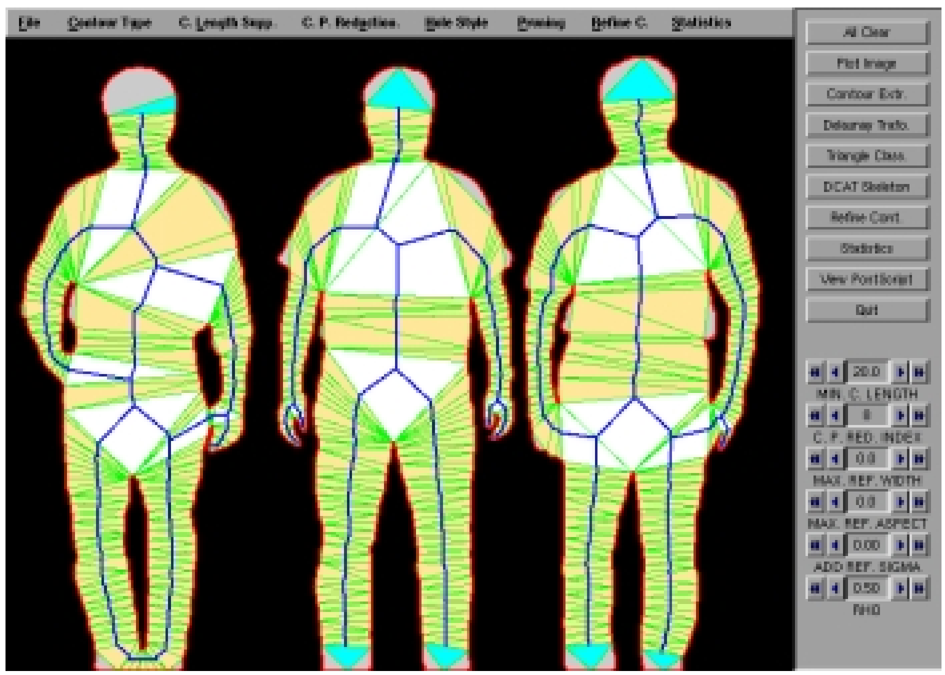

image of an object is provided (e.g., from motion based image differencing). From this, the objects contours are extracted with a newly developed algorithm [3]. The contours and their points are compressed by applying a Haar wavelet transform, and subsequent to this the Chordal Axis Transform (CAT) [1,2] is applied. The CAT provides a morphological decomposition of the shapes into simplicial chain complexes of shape features (limbs and torsos). Metrical attributes of these features, such as length, width, etc., are computed from the triangles in the chain complexes constituting them. Final pruning of morphologically insignificant shape features based on their metrical attributes, leads to the final characterization of shapes by attributed skeletons. Note, that we can handle many shapes simultaneously, regardless of their complexity (given, e.g., by the number of holes in a shape). One powerful aspect of this new approach is the high degree of data compression that can be achieved. For the example given in the figure, a factor of 5000 is possible starting from a full pixel image of three humans and ending with a final set of features that allow a unique identification. Note that the Delaunay triangulation of shapes is the key step that allows both feature extraction and substantial data compression.

Furthermore, if we assume that the segmentation and contour extraction of image blobs is implemented in hardware (ASIC) or firmware (FPGA), then the remaining image processing steps, which we denote here as geometric filtering (GF), take as little as 62 *ms* for our particular example. Hence, the processing of about 15 VGA resolution images per second (or more) is possible on our current development platform, which is a 400 *MHz* Intel Pentium II computer system with LINUX OS and GNU C-compiler. The computer algorithms which perform these tasks have been implemented by us in an advanced intelligent surveillance camera project here at Los Alamos National Laboratory. Another application, which is based on our current effort, is described in Reference [4].

Compression and Abstraction of Image Information

Three Humans	168948 pixels
Contour Extraction	7747 points
Wavelet Compression	915 points
Delaunay Triangulation	919 triangles
Feature Formation	206 features
Feature Pruning	32 features

Compression Factor ~ 5000

Table 1.

Speed Performnce
on 400-MHz Pentium II with LINUX OS

Three Humans	(GF: 62 ms)	
Contour Extraction	530 ms	89.5%
Wavelet Compression	12 ms	2.0%
Delaunay Tesselation	29 ms	4.9%
Triangle Classification	11 ms	1.9%
Feature Formation	7 ms	1.2%
Feature Pruning	3 ms	0.5%

GF: ~ 15 Images per Second

Table 2.

[1] L. Prasad, "Morphological Analysis of Shapes," *CNLS Newsletter*, No. 139, July '97, LALP-97-010-139, Center for Nonlinear Studies, Los Alamos National Laboratory.

[2] L. Prasad, R. Rao, "Morphological Analysis of Shapes," in *Special Feature, Theoretical Division Supplement to Self-Assessment 97/98*, Los Alamos, May 1998, LA-UR-98-1150, p. 107.

[3] B. R. Schlei, L. Prasad, "A Parallel Algorithm for Dilated Contour Extraction from Bilevel Images," Los Alamos Preprint LA-UR-00-309, cs.CV/0001024.

[4] B. R. Schlei, L. Prasad, A. N. Skourikhine, "Granular Materials Image Analysis," in this issue of *Special Feature.2000, Theoretical Division Supplement to Self-Assessment 99/00*, Los Alamos, April 2000, LA-UR-00-1, p 15.

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